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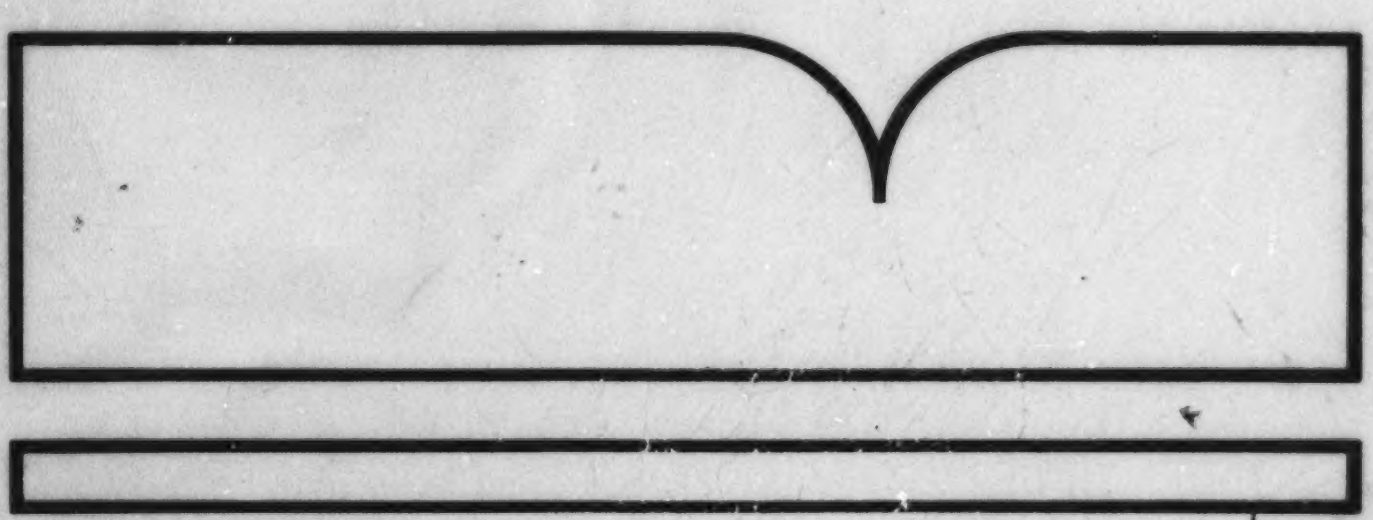

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16. ABSTRACT

Scientists in the United States and Canada have collaborated on the Cross-Appalachian Tracer Experiment (CAPTEX '83) using the perfluorocarbon tracer to simulate the long-range transport of pollutants in the atmosphere. The experiments, conducted in September and October of 1983 in the northeastern United States and southern Ontario, yielded approximately 3000 3-6-hour surface samples and over 1600 integrated airborne samples. In addition, supplemental meteorological data were measured. This paper describes the experiments and the data.

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CROSS-APPALACHIAN TRACER EXPERIMENT (CAPTEX '83)

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1. INTRODUCTION

Atmospheric transport and dispersion models are being used extensively to simulate the behavior of air pollutants and to estimate regional pollutant concentrations, depositions and source-receptor relationships. Increased concern over regional and international aspects of air pollution has created a need for reliable model calculations of concentrations as far as 1000 km from pollutant sources. Experimental verification of these calculations, via atmospheric tracer data, is essential to establish the credibility of the models and environmental assessments based on model simulations.

Development of a tracer system suitable for long-range atmospheric dispersion experiments was begun jointly by the Department of Energy and the NOAA Air Resources Laboratory about ten years ago. After investigation of many candidate tracers, a perfluorocarbon (perfluoro-monomethyl-cyclohexane: C_7F_{14}) was chosen. Released as a gas, it is inert, harmless, and can be accurately measured at its ambient background concentration of about 4 parts in 10^{15} parts of air (Ferber, et al. 1981).

Scientists in the United States and Canada have collaborated on a Cross Appalachian Tracer Experiment (CAPTEX '83) using the perfluorocarbon tracer to simulate long-range transport of pollutants in the atmosphere. The CAPTEX '83 experiments were conducted from mid-September through the end of October 1983. The main objectives were to test the tracer technology for application to 1000 km scale studies, to provide data to evaluate and improve computer models of pollutant transport and dispersion and to provide insight into the mechanisms involved in long-range transport and dispersion.

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* Jointly affiliated with the Air Resources Laboratory, NOAA.

2. TRACER RELEASES

Tracer was released from Dayton, Ohio on five separate occasions and from Sudbury, Ontario on two other occasions (Table 1). These locations were chosen, in part, because the Ohio Valley area and the Sudbury area are considered to contain significant pollutant sources affecting air quality in the northeastern U.S. and southeastern Canada. With one exception (release #6), tracer was released at ground-level over a 3-hr period on days when the lower atmospheric wind flow was expected to carry it over the sampling network.

Releases were planned for the early afternoon to allow good vertical mixing of the tracer. However, both Sudbury releases took place after midnight in well-mixed air masses behind cold fronts that provided the northwesterly winds required to carry the plumes over the sampling network.

3. DATA COLLECTION

3.1 Ground-Level Air Sampling

The CAPTEX '83 sampling sites, shown by the circles in Fig. 1, were arranged in arcs. These arcs were separated by approximately 100-km intervals, 300 to 1100 km from the Ohio release point.

The spacing of samplers along each arc approximates two plume standard deviations (intended to ensure plume measurements at two or more sites along each arc) and increases linearly with distance from Dayton. The density of sampling sites on the 800 km arc, passing through New York and New Jersey was doubled in order to provide more detail on plume structure. Several additional sites were placed just north of Lake Ontario to ensure that plumes from Sudbury would be measured at about 300 km, where the plume may still be fairly narrow.

The automatic sequential sampler used at each site consists of an Air Flow Module (lid) and a Power Control Module (base). The entire unit measures 36x25x20 cm and weighs 7 kg (15 lbs). The lid contains 23 sampling tubes filled with 150 mg of Ambersorb, which traps all the perfluorocarbons in the air flowing through the tube. The base contains a constant volume pump which draws air through each sampling tube in a sequence controlled by an internal digital clock. Flow rates, controlled by critical orifices, are selectable from 2 to 50 cc/min. The base also contains a digital printer that records the tube number, start time, and number of pump strokes (which can be converted to air volume) for each sample.

Controls in the base can be set for automatic start at a preselected day and time and for a preselected number of samples and duration of sampling (1 min to 1 week per tube). The controls also permit automatic analysis with a gas chromatograph. Power is supplied by internal rechargeable batteries or the sampler can be connected to an ordinary 110 VAC line. After 23 samples have been collected, the lid can be replaced by a fresh lid to continue the sampling program.

At the time of each tracer release, each sampling site operator was notified by telephone when to start sampling. Samplers nearest the release point were started a few hours before the expected arrival of the plume; the next group of samplers were started either 3 or 6 hours later and samplers further downwind were started at 6-hour intervals thereafter. Usually, six consecutive six-hour samples (total duration of 36 hours) were taken at each site; however, sites closest to the release point generally took 3-hr samples (total duration of 18 hours) for better definition of the plume. All operable samplers were used in each experiment regardless of the forecast direction of travel, with two exceptions, it was decided not to use the 300 km arc samplers on release #5 from Sudbury, and the Canadian sites were not used on release #6 from Dayton.

3.2 Aircraft Sampling

Seven aircraft were used during CAPTEX '83 to provide information on the vertical tracer distributions at various times after release. Battelle Pacific Northwest Laboratory (PNL) provided two aircraft stationed at Columbus, Ohio; Brookhaven National Laboratory (BNL) provided four stationed at Islip, New York; and Atmospheric Environment Service (AES) of Canada provided one from Ottawa, Ontario. Each aircraft used a modified automatic sequential sampler to collect tracer. In addition, one BNL aircraft was equipped with a real-time dual-trap analyzer.

The operational procedure for utilizing the aircraft was to stage them, prior to the tracer release, to one or several locations where the tracer plume was expected to pass. Various flightpath configurations using two or more aircraft were flown depending on many factors, such as time and distance from the staging locations to the forecasted plume center, flightpath length to traverse the expected plume width, total feasible sampling duration, number of sampling tubes and sample duration, weather restrictions, FAA flight restrictions, terrain height, and boundary layer height.

3.3 Meteorological Data

Upper-air wind data routinely were measured at the U.S. National Weather Service and the Canadian rawinsonde sites (Fig. 1). Whenever tracer was in the atmosphere over the region, upper-air soundings were increased to four per day at these network sites plus 10 Electric Power Research Institute (EPRI) sites operating on the same schedule. Supplemental soundings were taken at the tracer release sites several hours before and during the tracer releases. An Upper-Air Profiler, operated by the NOAA Wave Propagation Laboratory at Glens Falls, NY and auxiliary meteorological tower data were furnished by power companies in the CAPTEX area.

The Air Resources Laboratory Field Research Division released several constant-level tetroons simultaneously with the tracer releases at Dayton and Sudbury to serve as markers of the tracer plume and to provide additional information on atmospheric transport and dispersion. These tetroons were tracked by aircraft with on-board base stations consisting of a 403 mHz receiver, Loran-C navigator, a data acquisition/control unit and a computer that interprets the signals to compute the location (latitude, longitude, altitude) of the tetroon at any moment.

4. RESULTS

Preliminary analyses of the sampling data indicate that the experiment was a success. During all seven tracer releases, the plume travelled across the surface sampling network, as expected. Tracer released from Dayton was detected as far as New Hampshire. In all missions, sampling aircraft succeeded in detecting the plume after each release.

Table 1 summarizes the tracer releases, surface sampling schedule and aircraft sampling flights for each of the 7 experiments. During CAPTEX '83, about 3000 individual samples were collected from the surface network and analyzed by the Department of Energy Environmental Measurements Laboratory and BNL. In addition, over 1600 samples were collected in plume transects from 200 to 900 km downwind of the release point. A total of 13 tetroons was tracked, with varying degrees of success, up to 930 km from the tracer release point.

The following CAPTEX '83 data files will be available (on written request) from Carmen Benkovitz, Bldg. 51, Brookhaven National Laboratory, Upton, NY 11973:

a) September and October 1983 upper-air wind and temperature data at all mandatory and significant levels from the surface to 500 mb

b) Tower meteorological data (temperature and wind velocity) at eight sites at levels ranging from 9 to 230 m

c) Terrain elevations at 15-minute increments

d) Surface tracer concentration data

e) Aircraft sampling data (dates, times and locations of transect and spiral sampling and tracer concentrations)

f) Tetroon trajectory data.

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REFERENCE

Ferber, G. J.; K. Telegadas; J. L. Heffter; C. R. Dickson; R. N. Dietz; and P. W. Krey, 1981: Demonstration of a long-range atmospheric tracer system using perfluorocarbons. NOAA Tech. Memo. ERL ARL-101, Air Resources Laboratory, Rockville, Maryland. 74 p.

Figure 1. The CAPTEX '83 surface sampling network (circles), the normal national rawinsonde networks ('N'), the EPRI rawinsonde network ('E') and the Dayton, Ohio and Sudbury, Ontario tracer release sites ('R').

TABLE 1. SUMMARY OF CAPTEX '83 TRACER RELEASE AND SAMPLING DATA

Tracer Release Data					Surface Sampling Period		Aircraft Sampling Flight Data			
Number	Date	Period (GMT)	Amount (kg)	Site	First Samplers Started (GMT)	Last Samplers Ended (GMT)	Aircraft	Day/Time (GMT)	Region	Altitude (100 m,msl)
1	9/18	1700-2000	208	DAY[1]	9/18/1900	9/21/0700	PNL, BNL	9/19/0915-1700	Central NY	9,12,18,21,27
							AES	9/19/0915-1700	Central NY	15 3-30[4] 6-21[5]
2	9/25	1705-2005	201	DAY[2]	9/25/1800	9/28/1500	PNL	9/26/0045-0450	Northern OH	9,15,21
							BNL	9/26/1800-9/27/0100	Northeastern PA to Central NY	12,15,18,21
3	10/2	1900-2200	201	DAY[2]	10/2/2100	10/5/0600	PNL	10/3/0510-0800	North and Central OH	9,15,21
							BNL	10/3/1500-2300	Central NY to Central MD	12,15,18,24
							AES	10/3/1450-2345	Southern NY to Central PA	9,15,21,24 6-30[6] 6-24[7] 9-24[8]
4	10/14	1600-1900	199	DAY[2]	10/14/1800	10/16/1500	PNL	10/14/2225-10/15/0320	Southwestern PA to Southwestern NY	12,15,18
							BNL	10/15/0245-1200	Eastern PA, NJ, Southeastern NY to Central CT	9,12,15
							AES	10/15/0500-1355	Central CT to Southeastern NJ	9,15,18 9-30[9] 6-30[10]
5	10/26	0345-0645	180	SUD[3]	10/26/0800	10/28/0800	BNL	10/26/1905-10/27/0355	Southeastern NY to Northeastern NY	9,12,15,18
							AES	10/26/2030-10/27/0230	East Central NY	6,9,15 9-30[11]
6*	10/28	1530-1600	32	DAY[2]	10/28/1600	10/29/1300	None	-	-	-
7	10/29	0600-0900	183	SUD[3]	10/29/0400	10/30/1300†	PNL	10/29/1230-2335	Central and Southern NY and Central PA	12,15,18,24
							BNL	10/29/1235-10/30/0220	Central and Southeastern NY and Southern NY to Southern PA	9,12,15,18,21
							AES	10/29/1450-10/30/0230	East Central NY to Northeastern PA	24 9-30[12]

1 39.80°N, 84.05°W
2 39.90°N, 84.22°W
3 46.62°N, 80.78°W
* Canadian surface samplers did not operate during release #6.
† One sampler remained operational until 11/01/1300.

4 Spiral over Oswego, NY
5 Spiral over Syracuse, NY
6 Spiral over Williamsport, PA
7 Spiral over Harrisburg, PA
8 Spiral over Elmira, NY
9 Spiral over Danbury, CT
10 Spiral over Atlantic City, NJ
11 Spiral over Glens Falls, NY
12 Spiral over Allentown, PA